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Improvement in Fruit and Vegetable Consumption Associated with More Favorable Energy Density and Nutrient and Food Group Intake, But Not Kilocalories

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ABSTRACT

Background Children generally do not consume adequate amounts of fruits and vegetables (F/V). Eating more F/V can improve energy density and overall diet quality.

Objective Our aim was to investigate whether improvements in F/V consumption were associated with improvements in energy density, total calories, and dietary components related to F/V.

Design We performed secondary analyses of dietary data from a successful four-group randomized controlled trial promoting F/V. Data were collected at baseline, immediately after gameplay, and 3 months post intervention.

Participants/setting Preadolescent child–parent dyads (n=400) were recruited. Eligibility criteria were 4th- or 5th-grade child (approximately 9 to 11 years old) with Internet access and a parent willing to participate in the intervention. Complete dietary data were collected on 387 of the 400 child participants. The videogame was available online on a secure, password-protected website.

Main outcome measures Dietary intake was assessed with three unannounced dietary recalls collected at each data-collection period via telephone by trained staff using Nutrition Data System for Research software. Energy density and F/V, nutrient, and food consumption were calculated.

Statistical analysis performed A 4×3 (group by time) repeated measures analysis of covariance with mixed-effect linear models was used. Covariates included child's sex, race/ethnicity, and total energy intake as well as parent's age and household education. Energy was excluded as a covariate in the energy density and energy models.

Results Significant changes occurred in energy density. A significant interaction (group by time) was observed ($F_{6, 515}=2.40$; $P<0.05$) in energy density from food only, while a significant time effect was observed for energy density from all foods and beverages ($F_{2, 388}=13.75$; $P<0.0001$). Desirable changes were also observed in F/V-related dietary components.

Conclusions Increasing F/V consumption improved energy density and diet quality considerably in preadolescent children.
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CHILDHOOD OVERWEIGHT AND OBESITY COMPRISE A persistent, though preventable, public health epidemic, with 17% of North American children classified as obese during 2011 to 2014.[1] Consumption of excess kilocalories increases risk for overweight and obesity.[2] Energy-dense foods (eg, desserts, chips, fast food) contain more kilocalories in a given food weight and have been associated with increased risks of overweight and obesity.[3] Replacing energy-dense foods with those lower in energy density can decrease total kilocalorie consumption[4] and improve diet quality.[5,6] Fruits and vegetables (F/V) prepared without added fat or sugar have low energy density, yet are excellent sources of vitamin C, beta carotene, potassium, and fiber.[3] Thus, increasing F/V consumption can decrease total kilocalorie consumption[7] and improve diet quality,[5] particularly when F/V are promoted as replacements for foods higher in fat and added sugar. Research has suggested that higher F/V consumption was also related to decreased sodium intake, a risk factor for hypertension.[8,9] Because dietary behaviors track into adulthood,[10,11] increasing F/V consumption in preadolescent children can decrease future risk for overweight and obesity[12,13] and associated chronic diseases.[14,15]

Current national guidelines for 9- to 11-year-old children recommend 1.5 to 3.0 cup-equivalents of vegetables and 1.5 to 2 cup-equivalents of fruits per day, depending on age, sex, and activity level.[2] However, as in the past,[16,17] few children or adults meet their age-, sex-, and activity-specific recommendations,[2] further emphasizing the need to develop effective interventions to promote healthy dietary behaviors during childhood.[18] Although interventions to increase F/V intake among children are often delivered in person,[19] health-oriented videogames are emerging as a promising intervention approach.[20-22] *Squire's Quest! II: Saving the Kingdom of Five-A-Lot*[22] was a 10-episode, online, videogame designed to promote F/V consumption to preadolescent children. *Squire's Quest! II* demonstrated that children who created action plans as part of goal-setting increased F/V consumption immediately post intervention and maintained it 3 months later. This article examines whether the change in F/V intake was related to changes in energy density, total kilocalories, F/V-related nutrients, added sugar, and energy-dense foods (ie, snack chips, dessert foods, sweetened beverages).

MATERIALS AND METHODS

Study Design

Methods have been described in detail elsewhere.[22,23] Briefly, *Squire's Quest! II* was a 10-episode, online videogame designed to encourage 4th- and 5th-grade children (approximately 9 to 11 year olds) to consume at least five daily servings of F/V. Children (n=400) from a large state in the southwestern United States were randomized to one of four groups and data were collected at three times: baseline; post 1 (immediately post game play, which was approximately 3 months after baseline); and post 2 (approximately 6 months after baseline). Child was the unit of randomization and assignment. Randomization occurred after both parent and child completed baseline data collection. The primary outcome for the efficacy study was F/V consumption. The efficacy study was powered to detect a group difference of at least 0.51 servings of F/V.[22,23]

Groups varied with respect to type of implementation intention[24] (ie, a plan to facilitate goal attainment), which the children created as part of the goal-setting component. The "action" group created an action plan specifying how (ie, who, what, and when) they were going to meet their F/V goal. Children assigned to the "coping" group identified a potential barrier to goal attainment, and a solution they would enact if the barrier was encountered. In the "action and coping" group, children created both an action plan and a coping plan. Children in the "control" group set a goal, but did not create an action or coping plan.

Written parental consent and child assent was obtained before participation. The Institutional Review Board at Baylor College of Medicine reviewed and approved the protocol (H-18488). The trial was registered with ClinicalTrials.gov (ID: NCT01094004).

Setting

Participants played the videogame online on a secure, password-protected website from home or community settings. Recruitment began November 2009 and ended June 2010. Data collection began November 2009 (baseline) and ended on completion of post 2 assessments (March 2011). The intervention began immediately upon parent and child completion of baseline assessments; children were given approximately 3 months to complete the intervention.

Measurements

Three unannounced dietary recalls (2 weekdays, 1 weekend day) were conducted with the child only at each data-collection period by trained staff over the telephone using Nutrition Data System for Research.[25,26] Before baseline data collection, families received a booklet that assisted with identifying portion sizes for foods and beverages; the booklet was replaced at subsequent data-collection periods if it had been lost. Recalls were scheduled to be conducted during a 2-week period; however, family commitments and unexpected events sometimes extended the period of time during which recalls were collected. Dietary data-collection staff were blinded to group assignment. Energy density and energy intake were calculated using the Nutrition Data System for Research output. Energy density was defined as the amount of energy (kcal) in a given weight of food and/or beverages (or kcal/g). Due to controversy regarding the optimal methods for measuring and reporting energy density, energy density was calculated in two ways: 1) all foods and beverages consumed, including water, milk, and 100% juice (energy density-all); and 2) foods only (energy density-food only).[27] At each data-collection period, the 3-day dietary intake data were averaged to improve estimates of usual dietary intake for energy density-all; energy density-food only; kilocalories; F/V-related nutrients (vitamin C, beta carotene, potassium, dietary fiber, and sodium); added sugar; and energy-dense foods (snack chips, desserts, and sweetened beverages).

Statistical Analysis

Analyses were conducted using the Statistical Analysis Software.[28] Numerical (skewness, kurtosis, and Kolmogorov-Smirnov D) and graphical methods were used to test for data normality. Baseline demographic characteristics and primary outcomes were examined by group using χ^2 analysis and analysis of variance, respectively. Intent-to-treat analyses assessed the influence of dropouts on the effect of the intervention.

Intervention effects on energy density, nutrient intake, added sugar, and energy-dense foods were evaluated by mixed-effect linear models (Proc Mixed procedure in SAS[28]) using a 4×3 (group by time) factorial design. Global statistical significance (group by time interaction; group and time main effects) was set at $P<0.05$. If the F-statistic was significant, post hoc analyses were conducted. Because there were five contrasts of interest (ie, control vs action, control vs coping, control vs action and coping, baseline vs post 1, and baseline vs post 2), $P<0.01$ (0.05/5) with Bonferroni correction was used to control for family-wise error rate (type I error). Covariates for energy density and energy included child's sex and race/ethnicity, as well as parent's age and household education. Covariates for F/V-related nutrients and high energy-density foods included child's sex, race/ethnicity, and total energy intake, as well as parent's age and education.

RESULTS

Four hundred parent–child dyads completed baseline data collection and were randomized to a condition. Children

Table 1. Mean daily energy, energy density, and nutrient intake for 387 children participating in the *Squire's Quest II* videogame intervention, stratified by group and time obtained using mixed-effect analysis controlling for potential confounders[a]

Variable	Baseline	Post 1	Post 2	Change from Baseline[b] Post 1[c]	Post 2[c]
	←*mean (standard error)*→			←P *value*→	
ED[d]-all (kcal/g)[ef**]**					
Control	1.02 (0.02)	1.00 (0.02)	0.98 (0.02)	0.630	0.177
Action	1.06 (0.02)	1.00 (0.02)	0.95 (0.02)	0.061	<**0.0001**
Coping	1.04 (0.02)	1.01 (0.02)	1 (0.02)	0.521	0.231
Action and coping	1.01 (0.02)	0.96 (0.02)	0.94 (0.02)	0.163	**0.006**
ED-food only (kcal/g)[efg*]**					
Control	1.90 (0.04)	1.79 (0.04)	1.91 (0.04)	0.044	0.932
Action	1.95 (0.04)	1.78 (0.04)	1.76 (0.04)	**0.0006**	<**0.0001**
Coping	1.95 (0.04)	1.81 (0.04)	1.83 (0.04)	**0.002**	0.023
Action and coping	1.87 (0.04)	1.80 (0.04)	1.85 (0.04)	0.270	0.845
Energy (kcal)[e]					
Control	1,496 (34.71)	1,485 (38.84)	1,523 (39.09)	0.962	0.809
Action	1,477 (34.93)	1,490 (38.85)	1,444 (38.94)	0.945	0.727
Coping	1,487 (35.04)	1,473 (38.88)	1,510 (39.79)	0.930	0.862
Action and coping	1,476 (35.13)	1,467 (39.23)	1,482 (39.31)	0.976	0.987
Vitamin C (mg)[f*h]					
Control	96.89 (7.97)	88.04 (6.35)	92.66 (11.98)	0.586	0.922
Action	74.25 (8.01)	85.11 (6.36)	87.22 (11.91)	0.446	0.461
Coping	73.37 (8.03)	86.12 (6.38)	96.91 (12.11)	0.328	0.088
Action and coping	84.99 (8.04)	97.17 (6.45)	104.47 (11.98)	0.364	0.179
Beta carotene (μg)[f*h]					
Control	1,499 (191.00)	1,812 (234.58)	1,855 (300.67)	0.452	0.512
Action	1,557 (192.25)	1,925 (234.41)	2,529 (298.56)	0.330	**0.007**
Coping	1,208 (192.9)	1,780 (234.33)	1,727 (305.22)	0.070	0.249
Action and coping	2,254 (193.42)	1,905 (236.69)	2,203 (300.72)	0.374	0.986
Sodium (mg)[f*h]					
Control	2,655 (45.33)	2,511 (50.84)	2,740 (50.96)	0.035	0.328
Action	2,626 (45.58)	2,590 (50.81)	2,562 (50.70)	0.811	0.533
Coping	2,646 (45.71)	2,637 (50.79)	2,667 (51.91)	0.984	0.936
Action and coping	2,623 (45.81)	2,585 (51.30)	2,670 (51.14)	0.780	0.709
Potassium (mg)[f**h]**					
Control	1,732 (38.1)	1,798 (42.6)	1,789 (45.66)	0.301	0.466
Action	1,668 (38.35)	1,812 (42.61)	1,905 (45.47)	**0.003**	<**0.0001**
Coping	1,693 (38.48)	1,828 (42.65)	1,854 (46.42)	**0.007**	**0.003**
Action and coping	1,823 (38.59)	1,868 (43.04)	1,858 (45.86)	0.575	0.747

(*continued on next page*)

Table 1. Mean daily energy, energy density, and nutrient intake for 387 children participating in the *Squire's Quest II* videogame intervention, stratified by group and time obtained using mixed-effect analysis controlling for potential confounders[a] (*continued*)

				Change from Baseline[b]	
Variable	**Baseline**	**Post 1**	**Post 2**	**Post 1**[c]	**Post 2**[c]
	←——*mean (standard error)*——→			←——P *value*——→	
Total dietary fiber (g)[f****h]					
Control	11.02 (0.34)	12.13 (0.43)	11.5 (0.42)	0.021	0.486
Action	11.33 (0.35)	12.55 (0.43)	12.75 (0.42)	**0.008**	**0.0007**
Coping	11.16 (0.35)	12.46 (0.43)	12.14 (0.42)	**0.004**	0.056
Action and coping	11.4 (0.35)	12.08 (0.43)	12.15 (0.42)	0.224	0.173
Added sugars (g)[f****h]					
Control	54.74 (2.25)	52.79 (2.21)	48.2 (2.25)	0.737	0.037
Action	58.69 (2.26)	51.64 (2.21)	50.79 (2.24)	0.019	**0.008**
Coping	56.83 (2.26)	50.89 (2.21)	53.83 (2.29)	0.057	0.497
Action and coping	58.16 (2.27)	53.82 (2.23)	50.13 (2.26)	0.219	**0.007**

[a]Groups varied on type of implementation intention (ie, plan) created as part of goal-setting: control (none), action (action plan), coping (coping plan), action and coping (action and coping plans).
[b]Overall *F* test and contrasts assessing mean changes from baseline.
[c]Bold text indicates significant results from post hoc analyses.
[d]ED=energy density (kcal/g).
[e]Models were adjusted for child's sex, racial/ethnic group, parent age, and household education.
[f]Time.
[g]Interaction of group by time.
[h]Models were adjusted for child's sex, racial/ethnic group, parent age, household education, and total energy.
*$P<0.05$.
**$P<0.01$.
****$P<0.0001$.

were multi-ethnic (white 36.8%, Hispanic 27%, African American 26%) and 52.5% were female. Parents were mostly female (96.3%), multi-ethnic (white 40.5%, Hispanic 26.0%, African American 26.3%), 40 to 59 years old (55.5%), and married (77.5%). Children were predominantly from well-educated households (36.7% postgraduate study and 57.6% had a mean household income >$61,000). Nearly all participating children (n=387 [96.8%]) had complete dietary data (baseline, post 1, post 2). A diagram of participant flow through the study has been published previously.[22]

At baseline, mean energy intake was 1,484 kcal. Energy density-all was 1.03 kcal/g and energy density-food only was 1.94 kcal/g (data not shown). Regardless of time, analyses did not reveal significant group main effects for energy density, total energy, or nutrient intake. The only interaction effect (group by time) observed was for energy density-food only ($F_{6,\ 515}$=2.40; $P<0.05$) (Table 1). Post hoc analysis revealed that participants in the coping group (P=0.002) at post 1, and in action group at both post 1 (P=0.0006) and post 2 ($P<0.0001$), had significantly lower energy density-food only compared with baseline.

Significant time effects were observed for energy density-all ($F_{2,\ 388}$=13.75; $P<0.0001$), vitamin C ($F_{2,\ 392}$=3.09; $P<0.05$), beta carotene ($F_{2,\ 390}$=4.28; $P<0.05$), sodium ($F_{2,\ 389}$=3.37; $P<0.05$), potassium ($F_{2,\ 387}$=15.48; $P<0.0001$), total dietary fiber ($F_{2,\ 389}$=16.67; $P<0.0001$), and added sugar ($F_{2,\ 386}$=12.63; $P<0.0001$) (Table 1).

Compared with baseline, energy density-all was significantly lower at post 2 for the action ($P<0.0001$) and action and coping groups (P=0.006). Post hoc analyses revealed no significant changes from baseline for vitamin C or sodium. Beta carotene intake increased significantly for the action group at post 2 (mean changes=972 μg; P=0.007). Potassium intake was higher in both the action and coping groups at both post 1 (P=0.003, action; P=0.007, coping) and at post 2 ($P<0.0001$, action; P=0.003, coping). Total dietary fiber intake was higher at post 1 in both the action (P=0.008) and coping groups (P=0.004); however, only the action group displayed a significant increase at post 2 (P=0.0007). Added sugars were significantly lower at post 2 in the action (P=0.008) and action and coping groups (P=0.007).

Table 2 presents the food outcomes. Significant time effects occurred in servings of snack chips ($F_{2,\ 388}$=3.79; $P<0.05$) and desserts ($F_{2,\ 387}$=10.9; $P<0.0001$). The action group reported a significantly lower intake at post 2 (P=0.004) for both snacks and desserts. No significant group main effects or interactions (group by time) were detected.

DISCUSSION

To our knowledge, this is the first study to reveal that increased F/V intake fostered by a serious game intervention was significantly related to improvements in energy density, F/V-related nutrients, and energy-dense foods in preadolescent children.

Table 2. Mean daily food intake of selected foods for 387 children participating in the *Squire's Quest II* videogame intervention, stratified by group and time, obtained using mixed-effect analysis controlling for potential confounders[a]

Variable	Baseline	Post 1	Post 2	Change from Baseline[b] Post 1[c]	Post 2[c]
	←mean (standard error)→			←P value→	
Snack chips (serving)[de*]					
Control	0.23 (0.03)	0.23 (0.03)	0.24 (0.03)	0.981	1.000
Action	0.27 (0.03)	0.20 (0.03)	0.16 (0.03)	0.214	**0.004**
Coping	0.24 (0.03)	0.19 (0.03)	0.17 (0.03)	0.501	0.114
Action and coping	0.24 (0.03)	0.19 (0.03)	0.24 (0.03)	0.368	0.998
Dessert (serving)[de****f]					
Control	0.45 (0.03)	0.37 (0.03)	0.30 (0.03)	0.362	0.018
Action	0.46 (0.03)	0.31 (0.03)	0.30 (0.03)	0.019	**0.004**
Coping	0.40 (0.03)	0.31 (0.03)	0.28 (0.03)	0.224	0.076
Action and coping	0.37 (0.03)	0.30 (0.03)	0.31 (0.03)	0.381	0.465
Sweetened beverage (oz)[dg]					
Control	3.16 (0.10)	3.09 (0.10)	2.60 (0.10)	0.985	0.412
Action	4.25 (0.10)	2.89 (0.10)	3.11 (0.10)	0.020	0.082
Coping	3.17 (0.10)	3.34 (0.10)	3.21 (0.10)	0.925	0.996
Action and coping	3.90 (0.10)	3.69 (0.10)	3.20 (0.10)	0.920	0.368

[a]Groups varied on type of implementation intention (ie, plan) created as part of goal setting: control (none), action (action plan), coping (coping plan), action and coping (action and coping plans).
[b]*F* test and contrasts assessed mean changes from baseline.
[c]Bold text indicates significant results from post hoc analyses.
[d]Models were adjusted for child's sex, racial/ethnic group, parent age, household education, and "total energy."
[e]Time.
[f]Dessert included all cakes, cookies, pies, sweet rolls, pastries, and candy.
[g]Sweetened beverages included all sweetened drinks (coffee, tea, soda).
*$P<0.05$.
****$P<0.0001$.

Although a negative relationship has been observed between F/V intake and energy density in children,[4] there has been limited research demonstrating the effectiveness of interventions to increase F/V intake and lower energy density in children of this age. Therefore, the finding that the *Squire Quest! II* intervention increased F/V intake in preadolescent children and decreased energy density is a promising finding. Because dietary behaviors established in childhood tend to track into adulthood,[10,11] research is needed to validate novel and effective interventions to establish sustainable, health-promoting, dietary behaviors in children. Identifying and understanding the mechanisms underlying such dietary improvements could contribute to the development of more focused interventions to improve the dietary quality of preadolescent children.

Of note, only the action group displayed sustained decreases in energy density from foods only. This finding is consistent with the literature on implementation intentions[29] and suggests that helping children create action plans as part of goal setting is most effective for improving F/V consumption and decreasing energy density. Future research with preadolescent children is needed to examine longer-term effects on F/V intake and energy density over time and the ways in which interventions can enhance the likelihood of establishing sustainable dietary changes.

Similar to other reports,[13,30] significant improvements in intake of F/V-related nutrients and energy-dense foods were observed, suggesting that higher F/V consumption also improved diet quality. Decreasing intake of snack chips and desserts might partially explain the observed improvements in energy density. Although the *Squire Quest! II* intervention did not specifically target snack chips or desserts, it promoted increased F/V consumption at meals and snacks. Significant findings here include that setting meal- and snack-specific F/V goals, augmented with action plans, reduced dietary energy density, improved intake of F/V-related nutrients, and reduced intake of energy-dense foods. These important insights can guide design of interventions to increase F/V consumption in preadolescent children. Future research is needed to identify other effective approaches for goal setting,[31] as well as the amount of F/V necessary to reduce energy-dense food intakes and overall energy density.

Total energy intake (kilocalories) did not change overall or by group immediately after the intervention (post 1) or 3 months later (post 2). Although this contradicts other studies demonstrating a negative relationship between energy density and kilocalorie intake,[7] this negative observation is not surprising because neither reduced kilocalorie consumption nor weight loss was the focus of the *Squire Quest! II* intervention.

Even though decreases were observed for energy density, sweetened beverage intake did not change. This is not surprising, because sugar-sweetened beverage consumption was not targeted by the *Squire Quest! II* intervention. Furthermore, mean consumption of sugar-sweetened beverages in the children who participated in the *Squire Quest! II* study was <5 oz per day at all data-collection periods, which is substantially lower than that reported by others in preadolescent children.[32,33] This lower consumption can partially be explained by the higher socioeconomic status and household education levels of the sample, because consumption of sugar-sweetened beverage is influenced by income and education.[34,35]

Strengths of the current study and its design include its diverse cohort, high completion rate, robust sample size among completers to power the analyses, three registered dietitian nutritionist–assisted unannounced dietary recalls (including weekdays and weekends), novelty of the *Squire Quest! II* intervention, and focus on preadolescent children.

Limitations include lack of a group that did not set goals, uncontrolled timing of the intervention with respect to meals (because premeal gaming can suppress increased food intake among normal-weight boys[36]), not assessing body weight, and enrollment in only one region of the country (limiting generalizability). In addition, the *Squire Quest! II* study was originally powered to detect a change in F/V intake, not energy density. In addition, only food groups emphasized in the study were examined for changes in energy density. It is possible that other dietary behaviors changed, which could explain why overall energy intake did not decrease. Lastly, self-report of dietary intake has been shown to be error-prone,[37] and this is particularly true in children and adolescents.[38-40] Although the dietary recall method used in this study is an often-used method for collecting dietary data, it is based on self-report, and thus, is limited by children's age (which might have influenced accuracy of dietary data),[41] as well as their cognitive ability to recall foods consumed[38] and portion sizes.[42] In addition, mailing the portion-size booklet to children rather than providing in-person training in how to assess and report portion sizes is an additional limitation. The findings from this study should be interpreted with caution and these limitations may limit conclusions that can be drawn.

CONCLUSIONS

Encouraging preadolescent children to set goals and create action plans via a serious videogame increased F/V consumption of fruits and vegetables, decreased consumption of energy-dense foods, and improved intake of key nutrients.

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